Universidade de Aveiro Departamento de Biologia
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JOSÉ LUÍS SIMÕES DA CUNHA

POST-FIRE REGENERATION OF *Arbutus unedo* L. IN CENTRAL PORTUGAL – THE ROLE OF PLANT SIZE, FIRE SEVERITY AND DISTURBANCE HISTORY

REGENERAÇÃO PÓS-FOGO DE *Arbutus unedo* L. NO CENTRO DE PORTUGAL – TAMANHO DA PLANTA, SEVERIDADE DO FOGO E HISTORIAL DE PERTURBAÇÃO

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre Ecologia Aplicada, realizada sob a orientação científica do Professor Doutor Carlos Fonseca, Professor Associado com Agregação do Departamento de Biologia da Universidade de Aveiro e co-orientação científica da Doutora Paula Maia, Investigadora do Departamento de Biologia.

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keywords Forest fires, *Arbutus unedo*, plant size, fire severity, resprouters

abstract

Resprouting is a very important survival strategy that allows many plants to survive and recover after fire. Previous studies showed that pre-fire plant size and fire severity influence plants' resprouting ability. In this thesis we analysed the effects of fire severity and pre-fire plant size of *Arbutus unedo* L., a common Ericaceae found on the Mediterranean regions, on its resprouting ability after the fire on October, 2017 in Penacova, as well as different methodologies of sampling (measuring plant height, branch length and diameter, stalk, canopy and twigs diameter). The strawberry trees, from three different sites with different disturbance histories, were classified as tree-like or shrub-like according to their pre-fire characteristics and were monitored for a year, comprising two sampling campaigns. Result revealed that fire severity negatively influenced the resprouting ability of individuals by the end of the first campaign but its effect faded with time, which could indicate that fire severity is not the best long term predictor of post-fire regeneration on *Arbutus unedo*. Plant size (height, branch length and diameter and canopy area), however, were significantly correlated with its resprouting ability on both field campaign, wether in resprouts length, diameter or number. It was also established that some field measurements of pre-fire plant characteristics are redundant, so in similar future studies it should not be necessary to spend as much time and resources on sampling individuals by opting for the easiest or fastest measurement, knowing that branch diameter is the most reliable one since unlike lengths or heights, it can still be used after wood removals. It was not possible to obtain statistical results that would verify the existance of regeneration differences related to the different types of strawberry trees or the sampling sites, possibly due to the limited number of individuals available for sampling.

palavras-chave

Fogos florestais, *Arbutus unedo*, tamanho da planta, severidade do fogo, espécies rebrotadoras

resumo

Rebrotar é uma estratégia de sobrevivência muito importante que permite que várias espécies de plantas sobrevivam e recuperem o seu vigor após um incêndio. Estudos prévios mostram que o tamanho da planta antes do fogo, assim como a severidade desse mesmo fogo influenciam a sua capacidade de rebrotar. Nesta dissertação foram analisados os efeitos da severidade do fogo e o tamanho da planta antes do incêndio em *Arbutus unedo* L., uma Ericaceae muito comum das regiões Mediterrânicas, na sua capacidade de regeneração após o incêndio de outubro de 2017 em Penacova, assim como também diferentes metodologias de amostragem dos mesmos (medição de altura, comprimento de ramos, diâmetro de tronco, ramos, copa e galhos). Os medronheiros, de três parcelas com diferentes historiais de perturbação, foram categorizados como semelhante a árvore ou arbusto, conforme as características exibidas pelos mesmos antes do fogo e monitorizados ao longo de um ano, em duas campanhas de amostragem. Os resultados revelaram que a severidade do fogo influenciou negativamente a capacidade de regeneração dos indivíduos ao fim da primeira campanha de amostragem mas o seu efeito enfraqueceu com o tempo, o que poderá indicar que a severidade do fogo não é o melhor preditor de regeneração em *Arbutus unedo* a longo prazo. Já o tamanho da planta (altura, longitude e diâmetro do maior ramo e área da copa) antes do incêndio foi significativamente correlacionada com a capacidade de regeneração em ambas as campanhas, quer em longitude e diâmetro, quer em número total de rebentos por planta. Também ficou estabelecido que existem metodologias de medição de características das plantas antes do fogo que são redundantes entre si, daí em estudos futuros de características semelhantes não ser necessário despender tempo e recursos na medição de todas elas, podendo optar-se pela que seja mais fácil, rápida ou acessível, sendo que a medição de diâmetro de ramos é a mais conservativa pois, ao contrário de longitudes ou alturas, mesmo que haja um corte transversal ainda é possível medir com maior fiabilidade. Não foi possível obter resultados estatísticos que validassem a existência de diferenças na regeneração relacionadas quer com os dois tipos de medronheiros, quer com o local de amostragem, possivelmente devido ao limitado número de indivíduos para amostrar.

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1. Introduction

Fire is a very important ecological factor in the Mediterranean as it shapes the ecosystems, habitats and the species that inhabit it (Naveh 1989; Piussi 1992; Naveh 1994; Trabaud 1994; Rodrigo et al. 2004; Pausas and Keeley 2009; Moreira et al. 2011). In fact, Mediterranean shrub and tree species have developed survival strategies that allow them to overcome forest fires (Pausas 2001; Tapias et al. 2004; Rodrigo et al. 2004; Quevedo et al. 2007; Arnan et al. 2007; Rodrigo et al. 2012), wether by producing seeds that germinate post-fire or by resprouting. This last strategy can have a great impact on the plant communities since burned areas can rapidly be occupied by resprouting plants that may take as little as a few days to few weeks after fire to resurface (Hanes 1971; Keeley and Zedler 1978; Bond and Midgley 2001; Arnan et al. 2007). The resprouting process is characterized by three key phases: 1) surviving the fire; 2) resprouting vigour; and 3) resprouts survival (Moreira et al. 2012). These steps are crucial and allow plants to quickly settle back and reduces the chance of other plant species to establish themselves (Naveh 1975; Trabaud 1987; Trabaud 1994; Pausas et al. 1999; Arnan et al. 2013).

Arbutus unedo Linnaeus, an Ericaceae commonly known as strawberry tree is a species native to the Mediterranean region. Despite having a slow growth rate, when a disturbance occurs (e.g. fire) and removes the above-ground parts of the plant, its underground dormant buds are stimulated and the plant vigorously resprouts (Arnan et al. 2013). It was considered as an obligate resprouter, since its seeds aren't found on the soil seed bank and its seedlings take several years to establish (Mesléard and Lepart 1989), however recent studies (Vasques et al. 2013) give insight into its germination ecology, allowing to classify it as a facultative resprouter.

The fruit of *Arbutus unedo* has high content of sugars, dietary fibers, antioxidants like Vitamin C and organic acids that are precursors to omega-3 and omega-6 fatty acids (Alarcão-E-Silva et al. 2001; Ruiz-Rodríguez et al. 2011).

They can be eaten as fresh fruits but are usually used to make jam or marmalade and alcoholic beverages (Soufleros et al. 2005; Rivera et al. 2006).

Arbutus unedo has its importance in folk medicine since its fruits, leaves, bark and roots have medicinal properties and have been used to treat gastrointestinal disorders, diarrhea, urological and cardiac diseases, among others (El-Hilaly et al. 2003; Leonti et al. 2009).

With forest fires becoming an increasingly common hazard in Portugal, it is of the utmost importance understanding how the Mediterranean tree species react to them and to what degree they can survive and resprout. Previous studies on *Arbutus unedo* and other Mediterranean plant species have shown a positive response between the size of a plant and its capacity to resprout, meaning larger plants tend to resprout more vigorously (Pausas 1997; Konstantinidis et al. 2006). Additionally, fire severity, which has been described as the degree to which aboveground and belowground organic matter are consumed by fire (Keeley 2009) has been found to influence resprouting vigour, with more severe fires negatively affecting the number of resprouts on shrub species (Canadell et al. 1991; Ramón Obeso and Luisa Vera 1996).

The central goal of this study was to evaluate the post-fire resprouting of *Arbutus unedo* and to assess if and how fire severity and pre-fire plant size would affect its resprouting ability. The practical objective was to contribute to a better knowledge of the post-fire response of this species, under different silvicultural scenarios, to allow providing straightforward management guidelines, based on the prediction of its spontaneous regeneration.

To this end the growth of resprouts was monitored for one year after the October 2017 fire in three plots; one consisting on a plantation, the other two dominated by spontaneous mature strawberry trees.

2. Materials and Methods

2.1. Study area and disturbance history

The study area was located in the parish of São Pedro de Alva, municipality of Penacova, district of Coimbra, in between São Pedro de Alva and Hombres villages, in a transition area between Mesomediterranean and Thermo-submediterranean bioclimates (Rivas-Martínez 2009). According to an environment impact study (ProSistemas 1997) the study area is on a large shale patch of the “shale-schist complex” from the Cambrian period. These rocks have low permeability and thus poor aquifer resources.

The annual temperature range is 11.2ºC; August being the hottest month with a mean temperature of 20.6ºC and January the coolest with 9.6ºC. The highest air temperature registered is 41.0ºC in August and the minimum is -4.9ºC in January. The average annual precipitation is 1128 mm. The months with highest temperature (July and August) are the ones with the least precipitation, while the coldest ones are the rainiest months. The average number of frosting days in a year is 24.4, with December, January and February with higher incidence. The average annual wind speed has a very small variation throughout the year. The windiest month is March with 5.9 km/h wind speed and the least windy is October with 3.8 km/h winds. The total evaporation value per year is 1024.2 mm, with August as the month with highest evaporation (119.6 mm) and January with the lowest (56 mm).

However, weather conditions observed during the experimental period were quite different. During Spring, the first growth season after fire, the mean rainfall in the district of Coimbra was more than two fold the overall mean value, with the second rainiest March since 1931, and very heavy rainfall, hail and thunderstorm days in May. The mean temperature was also approximately 0.5ºC lower than the average during the same period (IPMA 2018a). Summer, the second growth season, also brought the second rainiest June and coldest July, both since 2000, while August was the second hottest of the last 88 years, the 4th of August being the hottest day of the XXI century (IPMA 2018b).

According to ICNF forest fire database and shapefiles, the parish of São Pedro de Alva was under 69 forest fires from the 80's to 2000. However, it was only possible to determine that the study area was affected in the period from 1990 to 1999, without knowing the actual years and times it was disturbed by fire and its severity (Figure 1).

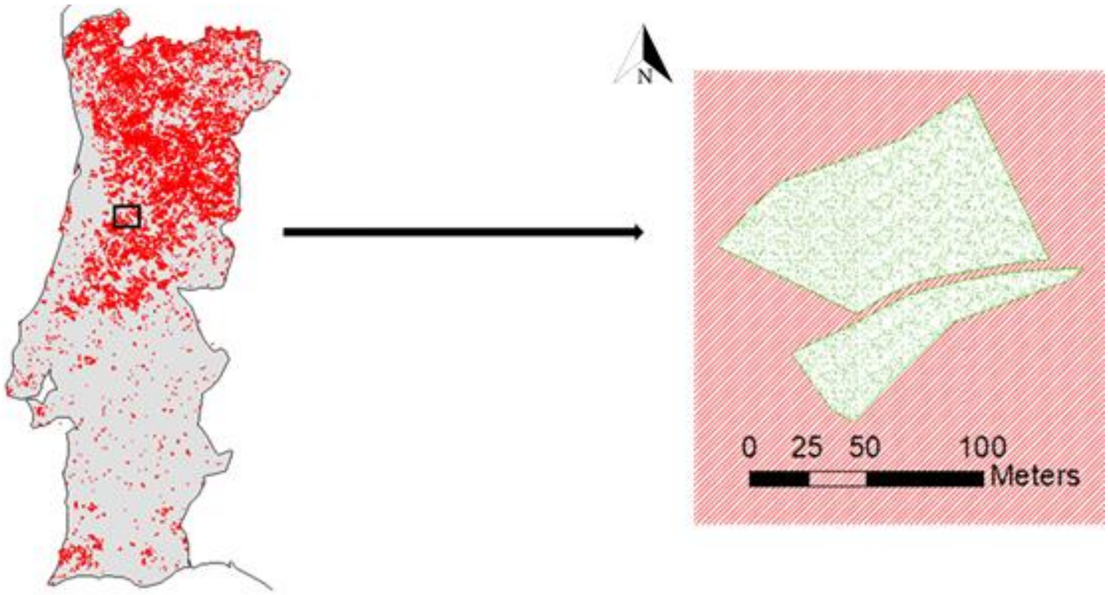

Figure 1- Location of the study area. Red areas represent the burned areas in Portugal from 1990 to 1999, which contain the study area (in green).

2.2. Sampling site description

This study was carried out on a site dominated by *Arbutus unedo* mature shrublands, surrounded by eucalypt plantations and some residual pine forest and agricultural fields. The plots were established according to the dominant species – *Arbutus unedo* – and management type – plots with planted strawberry trees and dominated by strawberry trees resulting from spontaneous regeneration (Figure 2).

In the mid 1950's all these plots were mainly pine forest, with some wild *Arbutus unedo* and *Quercus* spp. but over time each suffered distinct management related disturbances that will be further described.

Figure 2- Aerial photograph of the study area. 1- Costa da Nogueira 1, 2- Costa da Nogueira 2; 3- Faval. Photo by Bing Maps.

2.2.1. Costa da Nogueira 1 (plot 1)

This plot was converted to a *Eucalyptus globulus* plantation in the early 1950's and only recently converted to an *Arbutus unedo* plantation. By the time of fire the strawberry trees had been planted roughly four years ago. The plot is approximately 12 meters wide per 20 meters length and consists of 7 rows of planted strawberry trees, perpendicularly to the contour lines. This plot is roughly facing North, with a slope of approximately 25 degrees. The 22 individuals were sampled systematically along the plantation lines, only avoiding the border area and plants that were too consumed to allow for reliable estimations of pre-fire plant size.

2.2.2. Costa da Nogueira 2 (plot 2)

This plot is located in the same slope as the previous (plot 1). The mature pines were cut decades ago and it was then left without specific management since then. This resulted in a mature shrubland, dominated by *Arbutus unedo* and sparse *Quercus* spp., where some recent, but not systematical, silvicultural practices have been tested in order to improve fruit yield. The plot was about 20 meters wide per 30 meters long. Individuals were selected using the nearest neighbour selection whenever possible. A total of 30 plants were sampled.

2.2.3. Faval (plot 3)

The early pine forest that once covered this plot was cut and it was left with no further management, apart from standard fuel management. Strawberry trees spontaneously grew over time and the plot consisted of a mature *Arbutus unedo* shrubland, with some sparse adult pines at the time of fire. The sampled area is a south facing slope with approximately 20 degrees steep. The plot was 10 meters wide per 25 meters long. Individuals were also selected according to their nearest neighbour and 40 plants were sampled.

2.3. Sampling methodology

2.3.1. Autumn 2017 (Post-fire)

a. Plant Description

Burned *Arbutus unedo* on all three plots were selected and sampled (Supplementary Material 1) and photographs were taken (Supplementary Material 4). The strawberry trees were divided in two categories: tree-like if branching occurred above ground and the plant had a distinct trunk; shrub if branching occurred on ground level and the plant didn't have a differentiated trunk. Each tree had its height and crown diameter measured with a tailor's' measuring tape, with the crown being measured in two different axis, x and y, perpendicular and parallel to the slope, respectively. Canopy area was then calculated using the ellipse area (A) formula ($A= x/2*y/2*\pi$). Tree-like plants also had their height of branching measured (from the ground until branching) and basal diameter measured (10 centimeters above soil), the last one using a digital caliper. Up to 5 branches were measured in each plant, in a clockwise manner, starting on the x axis and always including the longest branch. The branches were measured from its insertion to the trunk (tree like plants) or root crown (shrub like plants), through its longest ramification up to its twig. They also had their diameters measured 10 centimeters above the insertion. Thicker branches which couldn't be measured with the digital caliper had their perimeter measured with the tailor's measuring tape and then the diameter (d) was calculated using the formula of the perimeter (P) of the circle ($d= P/\pi$).

b. Fire severity

In order to estimate fire severity, all previously sampled branches had 5 of its finest twigs measured 1 cm from the tip. A fire severity index was made by dividing the mean value of the finest twigs measured on each branch by the thickest twig observed, on scale from 0 to 1 (Maia et al. 2012).

Measurement of fire severity at the ground level was also considered. In this sense, soil cover on a 50 centimeter radius from the strawberry tree was analysed. Its cover was estimated as a percentage of rocks, litter, ashes (its colour and depth were registered), bare soil and plant regeneration. However, this analysis was abandoned after the first campaign, since preliminary data analysis revealed a high homogeneity amongst these variables between and within plots. Therefore, the present work does not reflect this assessment.

2.3.2. Spring 2018 (first sampling campaing)

Between April and May 2018 the total number of resprouts on each strawberry tree was counted. Up to five sprouts were selected (the ones who appeared to be the longest) and marked with coloured copper cables around them (Figure 3) and had their length measured with a taylor's measuring tape. Its diameter was also measured with a digital caliper, as close to the ground as possible while avoiding its branches and leaves. The total number of branches, leaves and buds were also counted (Supplementary Material 2) and photographs of all sampled resprouts taken (Supplementary Material 4).

Figure 3- *Arbutus unedo* resprout marked with coloured string.

2.3.3. Summer 2018 (second sampling campaing)

At the end of the drought season (September), the total number of resprouts on each strawberry tree was counted once again to determine if it increased or else, if sprout mortality had occurred. Previously marked resprouts were re-sampled (Figure 4) as in the previous growth season to evaluate their growth (Supplementary Material 2) and photographs were taken again (Supplementary Material 4).

Figure 4- *Arbutus unedo* resprouts on their second growth season

2.4. Statistical analysis

The effect of the pre-fire plant size on the resprouting response of the strawberry trees was investigated by means of Spearman correlations. This non-parametric test was selected after analyzing the data's trends regarding the assumptions for parametric correlations, such as Pearson's. Accordingly, the comparison between plots was made using the non-parametric Kruskal-Wallis test, followed by pairwise post hoc tests (Supplementary Material 3).

The dependent variables number, length and diameter of resprouts were correlated with the independent variables pre-fire plant height, canopy area, longest branch length and diameter.

Fire severity index was correlated with the dependent variables, to evaluate fire severity effect in post-fire *Arbutus unedo* regeneration, and also with the independent variables (pre-fire tree size estimations) to evaluate the importance of plant size in crown fire severity.

Correlations between field measures of height, branch length, branch diameter and basal diameter (if applicable) were made to test for redundancy in dependent variables. These tests were taken to understand if the methodology could be simplified in future research. A simplified methodology would result in a faster, cheaper approach and also would allow for timely eventual management measures.

All tests were carried out with IBM SPSS Statistics v25.

3. Results

3.1. Pre-fire plant size on the 3 plots

All sampled strawberry trees had their height, longest branch length and diameter and finest twigs measured and the mean values were used to describe each plot (Figure 5).

Plot 1 consisted of 22 planted trees, with 12 classified as tree-like and 10 as shrubs. Tree-like plants had a mean height of 105.8 cm while shrub-like plants averaged 85.2 cm. Tree-like plants also had higher longer average branch, measuring 98.9 cm against shrubs 91,4 cm. Trees also had a mean finest twig value of 1.73mm and shrubs were slightly larger with 2.09 mm. Overall, plot 1 plants averaged 21.30 mm diameter, 94.57 cm height, 94.77 cm longest branch and 1.93 mm thinnest twig.

Plot 2 had 27 shrubs and 3 trees. The mean height of the trees was 360 cm and srubs was 387.97 cm. Tree’s mean longest branch was 336.7 cm and shrubs was 495.4 cm. Trees had a mean value of 3.1 mm finest twig, while shrubs had 2.24 mm. Total means were 385.17 cm for height, longest branch was 479.50 cm, diameter was 75.89 mm and finest twig was 2.25 mm.

Plot 3 was composed of 40 shrub-like plants. The mean height of the shrubs was 289.6 cm, with a mean branch length of 333.0 cm and a mean finest twig of 2.40 mm.

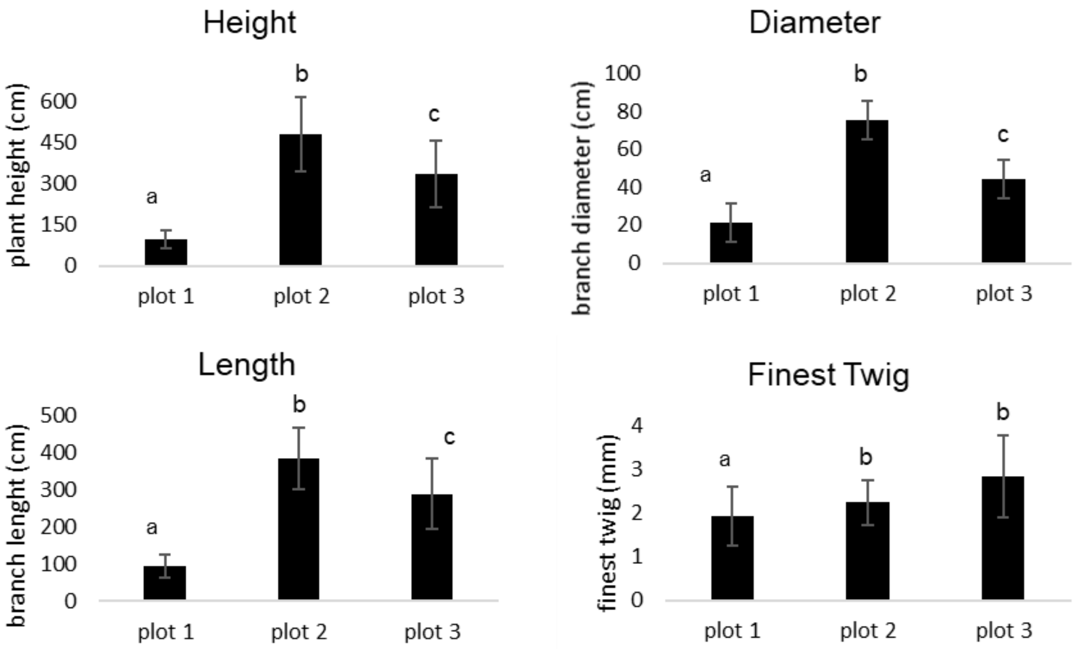

Figure 5- Description of the study plots, showing mean values of the size of the pre-fire plants of *Arbutus unedo*. – plant height (cm), branch diameter (mm), branch length (cm) and measurements of fire severity at the canopy level – diameter of the finest twigs (mm). Bars are standard deviations. Different letters indicate statistically significant differences (with Kruskal-Wallis test).

3.2. Fire Severity

Fire severity index (FSI) was based on the measurements of the finest twigs remaining in each plant after fire. This index was used to illustrate the degree of canopy burn on each sampled *Arbutus unedo* (Figure 6). Additional measurements on fire severity on other components of the vegetation were initially included, but were abandoned at the early stages of sampling, since no remaining litter was found on the surface of the soil and cover by rocks, ashes and bare soil were homogenous among all samples. Additionally, no plant regeneration was observed at the time of the first sampling season.

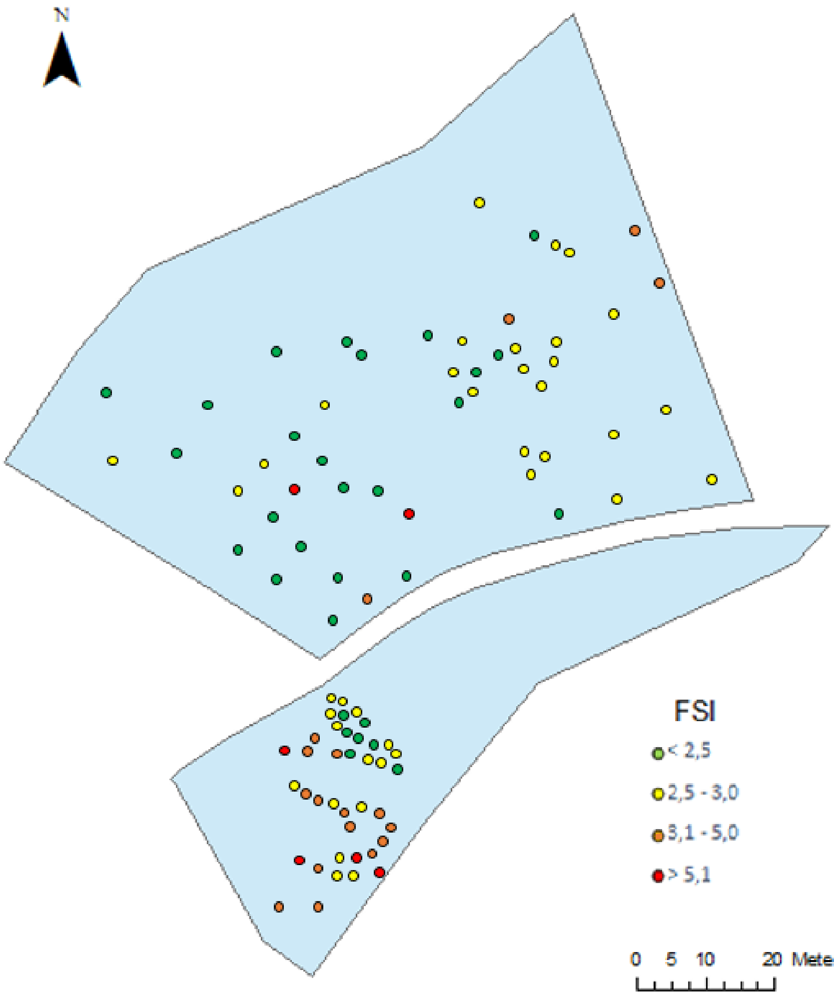

Figure 6- Schematic representation of the sampled *Arbutus unedo* and their fire severity according to the fire severity index.

Table 1 gives information on the mean and standard deviation of fire severity index values.

The mean fire severity index on plot 1 was 0.25 for trees 0.33 for shrubs while in plot 2 shrubs and trees had the same mean value ($\bar{x}$=0.32) and plot 3 was 0.42. So, in average, plot 1 was the least burned of them all while plot 3 was the most burned. It is also possible to observe that shrubs had a mean higher fire severity index than trees (0.37 on shrubs, 0.27 on tree-like plants).

Table 1- Mean and standard deviation fire severity index values for plots, plant types and total data

	Fire severity		
	$\bar{x}$	std	N
Plot 1	0.30	0.12	22
Plot 1 shrubs	0.33	0.15	12
Plot 1 trees	0.25	0.04	10
Plot 2	0.32	0.06	30
Plot 2 shrubs	0.32	0.05	27
Plot 2 trees	0.32	0.14	3
Plot 3	0.42	0.06	40
All shrubs	0.37	0.13	79
All trees	0.27	0.07	13
Total	0.36	0.12	92

Table 2 presents Spearman correlation values and significance measures between fire severity index and pre-fire plant height and canopy area (other variables in Supplementary Material 5). Significant results were found on plot 1 (ρ=-0.477, p=0.025), plot 1 shrubs (ρ=-0.685, p=0.014), plot 3 (which consisted of only shrub-like plants) (ρ=-0.229, p=0.042) and all shrub plants only (ρ=-0.406, p=0.009) regarding fire severity index and canopy area.

Table 2- Spearman correlation values (ρ) and significance measures (p) for the correlation between fire severity index and pre-fire plant height and canopy area.

		Fire severity		N
		ρ	p	
Plot 1	height	-0.371	0.089	22
	canopy	-0.477*	0.025	
Plot 1 shrubs	height	-0.518	0.084	12
	canopy	-0.685*	0.014	
Plot 1 trees	height	0.03	0.934	10
	canopy	-0.297	0.405	
Plot 2	height	0.226	0.231	30
	canopy	-0.077	0.685	
Plot 2 shrubs	height	0.261	0.189	27
	canopy	-0.118	0.556	
Plot 2 trees	height	-0.5	0.667	3
	canopy	-0.5	0.667	
Plot 3	height	-0.199	0.219	40
	canopy	-0.406**	0.009	
All shrubs	height	-0.081	0.477	79
	canopy	-0.229*	0.042	
All trees	height	0.11	0.721	13
	canopy	0.022	0.943	
Total	height	0.112	0.287	92
	canopy	-0.008	0.941	

**correlation is significant at the 0,01 level
* correlation is significant at the 0,05 level

3.3. Redundant measurements

The correlation between plant height and branch length (Figure 7) was r^2= 0.92, while correlations between branch diameter and length was r^2=0.79 (Figure 8), plant height and branch diameter was r^2=0.68 (Figure 9) and between basal diameter and height was r^2=0.72 (Figure 10). Overall, these measurements appear to be highly redundant.

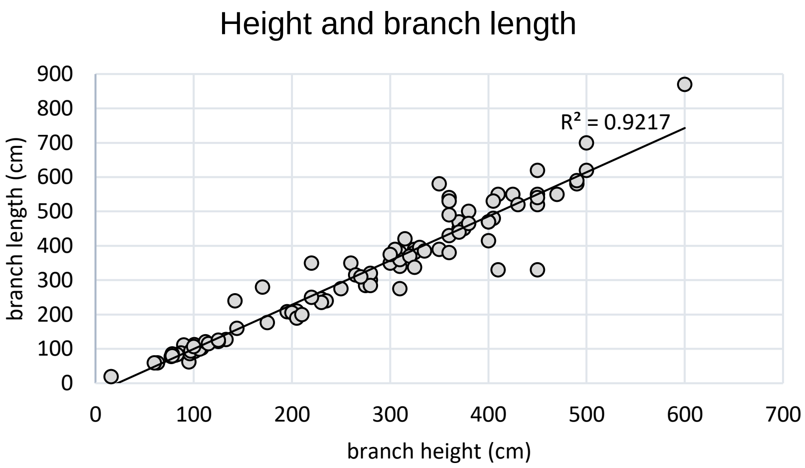

Figure 7- Correlation between branch height and branch length.

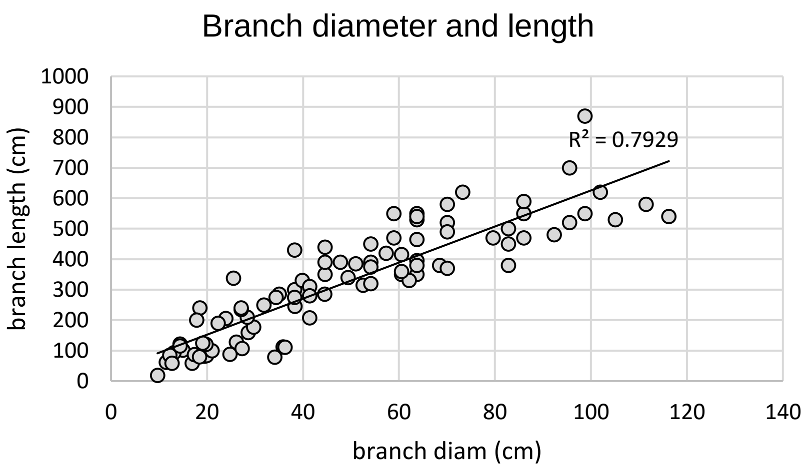

Figure 8- Correlation between branch diameter and branch length.

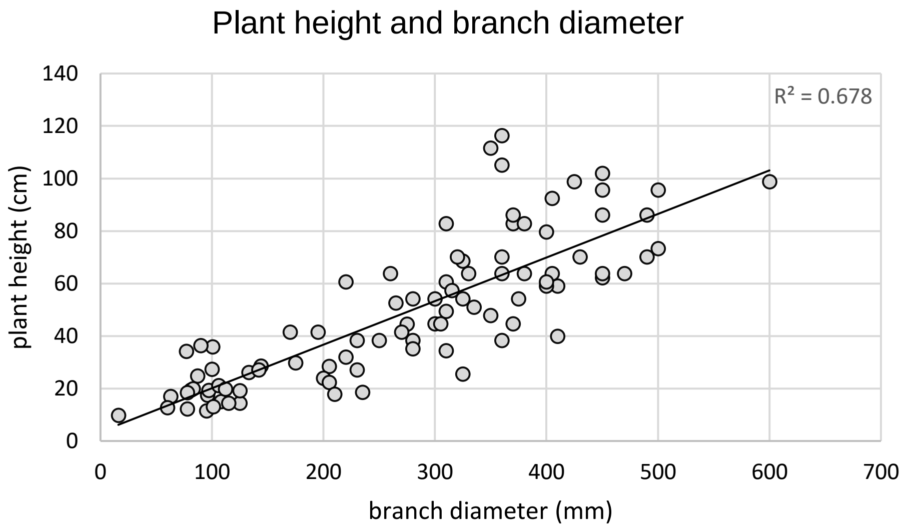

Figure 9- Correlation between plant height and branch diameter

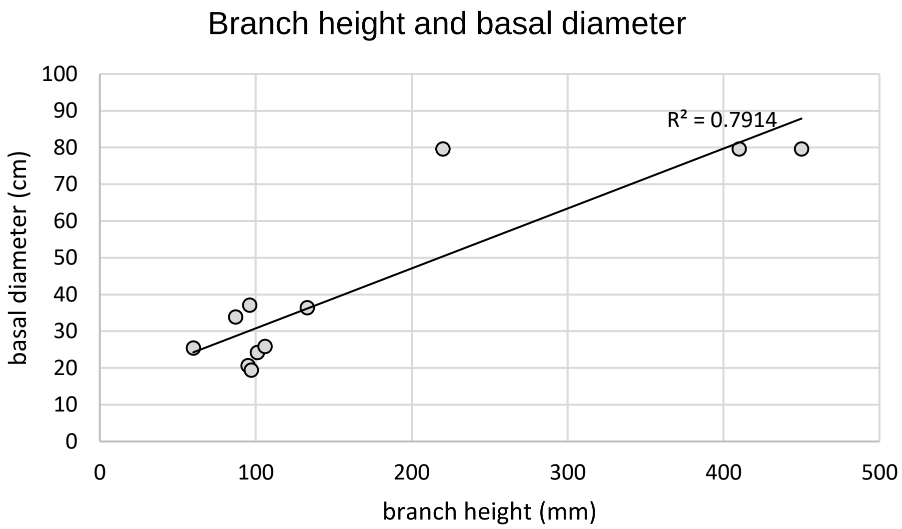

Figure 10- Correlation between branch height and basal diameter

3.4. Post-fire regeneration metrics

On spring and summer, previously sampled *Arbutus unedo* were sampled for its resprouting ability. Tables 3 and 4 provide comparative information (number, length and diameter, other variables in Supplementary Materials 6 and 7) on resprout development over the course of the year. It is possible to observe that Plot 1 plants had a lower mean number of resprouts on both seasons (5.41 and 7.48 on first and second seasons, respectively) when compared to Plots 2 and 3 (10.7 and 8.28 for 2 and 3 on spring and 19.4 and 21.73 on summer, respectively). When comparing trees and shrubs, it is also verified that trees had a lower mean number of resprouts across both seasons (5 and 7 on spring and summer against 9.68 and 19.62, respectively).

Table 3- Mean and standard deviation values for post-fire regeneration metrics in spring (first campaign) for number of resprouts, length (cm) and diameter (mm). Resprouts were sampled between 10th and 30th May 2018.

		No. resprouts	Length (cm)	Diameter (mm)	N
Plot 1	x̄	5.41	23.17	4.41	22
	std	4.56	14.13	2.37	
Plot 1 shrubs	x̄	8.3	27.97	5.33	12
	std	4.64	12.17	1.33	
Plot 1 trees	x̄	4.5	28.75	5.45	10
	std	2.27	5.74	1.01	
Plot 2	x̄	10.7	41.47	8.09	30
	std	11.99	19.1	6.34	
Plot 2 shrubs	x̄	11.62	43.54	8.63	27
	std	12.42	18.55	6.56	
Plot 2 trees	x̄	6.33	37.33	6.17	3
	std	7.57	7.02	1.39	
Plot 3	x̄	8.28	35.23	7.44	40
	std	16.84	18.72	2.29	
Shrubs	x̄	9.68	38.12	7.77	79
	std	14.39	17.68	4.15	
Trees	x̄	5	31.09	5.65	13
	std	3.97	7	1.1	
Total	x̄	9.07	37.21	7.5	92
	std	13.58	16.83	3.96	

Table 4- Post-fire regeneration metrics in summer (second campaign) for number of resprouts, length (cm) and diameter (mm). Resprouts were sampled between 10th and 13th September 2018.

		No. resprouts	Length (cm)	Diameter (mm)	N
Plot 1	x̄	7.48	81.41	11.42	22
	std	4.14	40.4	5.97	
Plot 1 shrubs	x̄	9.25	96	13.31	12
	std	3.74	24.47	3.61	
Plot 1 trees	x̄	5.78	103.88	14.77	10
	std	2.99	14.72	3.47	
Plot 2	x̄	19.4	102.6	13.07	30
	std	13.78	34.6	4.9	
Plot 2 shrubs	x̄	21.15	108.88	13.98	27
	std	13.69	26.97	4.18	
Plot 2 trees	x̄	10.67	82.33	9.52	3
	std	8.08	43.32	3.74	
Plot 3	x̄	21.73	101.58	15.62	40
	std	12.7	48.01	6.76	
Shrubs	x̄	19.62	109.08	15.57	79
	std	12.82	31.36	4.57	
Trees	x̄	7	98	13.34	13
	std	4.82	25.06	4.15	
Total	x̄	17.93	107.61	15.28	92
	std	12.8	30.7	4.56	

3.5. Resprout vigour and mortality

The strawberry trees presented very high regeneration rate (Table 5), with 92.4% samples regenerating by the end of spring 2018 (first campaign) and 97.8% by the end of summer 2018 (second campaign). Only 1 shrub hadn't resprouted on Plot 1 and 1 shrub on Plot 2 by the end of the second sampling campaign.

Table 5- Number of regenerating Arbutus unedo samples in each sampling campaign.

Samples	Spring	Summer
Plot 1	18	21
Plot 1 shrubs	9	11
Plot 1 trees	9	10
Plot 2	29	29
Plot 2 shrubs	28	28
Plot 2 trees	1	1
Plot 3	38	40
All shrubs	75	79
All trees	10	11
Total	85	90
N	92	92
Total % regenerating	92.39	97.83

3.6. Effect of fire severity on *Arbutus unedo*'s resprouting ability

Fire severity appeared to have a negative effect on early post-fire regeneration of *Arbutus unedo*, since the number of resprouts was negatively correlated for shrub-like plants (ρ=-0.316; p=0.006) and for the entire data set (ρ=-0.230; p=0.034) on the spring campaign (Table 6) (other spearman correlations on fire severity index and regeneration measurements on Supplementary Material 8). However, this correlation was not verified in the data from the summer campaign, unless on plot 2 (ρ=-0.479, p=0.009) and plot 2 shrubs (ρ=-0.522; p=0.006) (Table 6).

Table 6- Spearman correlation values (ρ) and significance measures (p) for the correlation between fire severity index and the number of resprouts on each Arbutus unedo specimen for each field campaign.

	Spring		Summer		N
	ρ	p	ρ	p	
Plot 1	-0.071	0.779	-0.063	0.787	22
Plot 1 shrub	-0.355	0.314	-0.545	0.067	12
Plot 1 tree	0.472	0.237	0.471	0.201	10
Plot 2	-0.188	0.328	-0.479**	0.009	30
Plot 2 shrub	-0.161	0.431	-0.522**	0.006	27
Plot 2 tree	-0.5	0.667	-0.5	0.667	3
Plot 3	-0.253	0.126	0.031	0.849	40
All shrubs	-0.316**	0.006	-0.027	0.816	79
All trees	0.192	0.572	-0.014	0.965	13
Total	-0.230*	0.034	0.124	0.246	92

**correlation is significant at the 0,01 level
* correlation is significant at the 0,05 level

3.7. Pre-fire plant size's effect on resprouts

3.7.1. Pre-fire plant length

Overall, the length of the longest branch of the pre-fire plant significantly affected the length of resprouts on both seasons (other spearman correlations between pre-fire plant length and more regeneration metrics on Supplementary Material 9). Nevertheless, this positive and significant correlation was only observed when taking the entire dataset into account, both after the first and second field campaigns (spring: ρ=0.234; p=0.031; summer: 0.25, p=0.022) and on the specific case of plot 1 in the summer (shrub-like plants - ρ=0.758; p= 0.011; all plants: ρ=0.509; p=0.031).

Table 7- Spearman correlation values (ρ) and significance measures (p) for the correlation between pre-fire plant length and resprouts maximum length.

	Spring		Summer		N
	ρ	p	ρ	p	
Plot 1	-0.189	0.452	0.509*	0.031	22
Plot 1 shrubs	-0.127	0.726	0.758*	0.011	12
Plot 1 trees	-0.31	0.456	-0.167	0.693	10
Plot 2	-0.032	0.869	0.171	0.375	30
Plot 2 shrubs	-0.081	0.695	0.11	0.592	27
Plot 2 trees	0	1	0.866	0.333	3
Plot 3	0.09	0.59	0.325	0.053	40
All shrubs	0.182	0.12	0.225	0.057	79
All trees	0.326	0.327	-0.159	0.64	13
Total	0.234*	0.031	0.250*	0.022	92

**correlation is significant at the 0,01 level
* coreelation is significant at the 0,05 level

3.7.2. Pre-fire plant diameter

When considering all samples grouped together, the diameter of the pre-fire plant was significantly and positively correlated (Table 8) with the diameter of resprouts on both sampling campaigns (spring: ρ=0.279, p=0.010; summer: ρ=0.290, p=0.008) (Table 8). It was also observed that plot 2 trees perfectly correlated with the pre-fire diameter but it should be noted that only 3 individuals fit the criteria (other correlations between pre-fire plant diameter and regeneration metrics on Supplementary Material 10).

Table 8- Spearman correlation values (ρ) and significance measures (p) for the correlation between pre-fire plant diameter on the maximum diameter of resprouts.

	Spring		Summer		N
	ρ	p	ρ	p	
Plot 1	-0.011	0.964	0.28	0.261	22
Plot 1 shrubs	0.042	0.907	0.442	0.2	12
Plot 1 trees	-0.333	0.42	0.143	0.736	10
Plot 2	-0.067	0.73	-0.016	0.936	30
Plot 2 shrubs	-0.19	0.352	-0.145	0.481	27
Plot 2 trees	1**	.	1**	.	3
Plot 3	0.053	0.752	0.059	0.732	40
All shrubs	0.165	0.159	-0.049	0.68	79
All trees	0.082	0.811	-0.427	0.19	13
Total	0.279**	0.010	0.290**	0.008	92

**correlation is significant at the 0,01 level
* coreelation is significant at the 0,05 level

3.7.3. Pre-fire plant height

Table 9 displays correlations between pre-fire plant height and several regeneration metrics.

When analysing the entire dataset, the height of the pre-fire plant significantly affected the length (ρ=0.222, p=0.041) and diameter (ρ=0.346, p=0.001) of resprouts on the first campaign and their number (ρ=0.472, p=0.000) and length (ρ=0.218, p=0.047) on the second. On a more individual analysis, it was observed that pre-fire plant height was significantly correlated to all shrubs diameter (ρ=0.209, p=0.036) on spring campaign. On the summer campaign, pre-fire plant height was significantly correlated to resprout length on plot 1 (ρ=0.598, p=0.009), plot 1 shrubs (ρ=0.709, p=0.022) and all shrubs (ρ=0.241, p=0.041). Finally, pre-fire plant height was also significantly correlated to the diameter of resprouts on plot 1 (ρ=0.540, p=0.021) and number of resprouts for plot 3 (ρ=0.434, p=0.005) and all shrubs (ρ=0.401, p=0.000).

Table 9- Spearman correlation values (ρ) and significance measures (p) for the correlation between pre-fire plant height and the number, maximum length and maximum diameter of resprouts.

		Spring		Summer		N
		ρ	p	ρ	p	
Plot 1	No. resprouts	-0.101	0.691	-0.071	0.761	22
	Length	-0.158	0.531	0.598**	0.009	
	Diameter	0.243	0.332	0.540*	0.21	
Plot 1 shrubs	No. resprouts	-0.135	0.711	0.19	0.555	12
	Length	-0.297	0.405	0.709*	0.022	
	Diameter	0.224	0.533	0.382	0.276	
Plot 1 trees	No. resprouts	-0.013	0.976	-0.095	0.823	10
	Length	-0.214	0.61	0.548	0.16	
	Diameter	0.024	0.955	-0.227	0.557	
Plot 2	No. resprouts	-0.352	0.061	-0.067	0.731	30
	Length	-0.16	0.406	0.001	0.994	
	Diameter	-0.128	0.509	-0.031	0.873	
Plot 2 shrubs	No. resprouts	-0.255	0.209	-0.03	0.873	27
	Length	-0.19	0.353	0.095	0.645	
	Diameter	-0.183	0.371	-0.03	0.883	
Plot 2 trees	No. resprouts	-0.5	0.667	-0.5	0.667	3
	Length	0.5	0.667	-0.5	0.667	
	Diameter	0.5	0.667	0.5	0.667	
Plot 3	No. resprouts	0.246	0.136	0.434**	0.005	40
	Length	0.118	0.482	0.32	0.057	
	Diameter	0.125	0.456	0.305	0,07	
Shrub	No. resprouts	0.107	0.366	0.401**	0	79
	Length	0.163	0.165	0.241*	0.041	
	Diameter	0.244*	0.036	0.13	0.275	
Tree	No. resprouts	-0.126	0.712	0.105	0.744	13
	Length	0.355	0.284	-0.245	0.467	
	Diameter	0.209	0.537	-0.273	0.417	
Total	No. resprouts	0.090	0.411	0.472**	0.000	92
	Length	0.222*	0.041	0,218*	0.047	
	Diameter	0.346**	0.001	0.130	0.242	

**correlation is significant at the 0,01 level

* correlation is significant at the 0,05 level

3.7.4. Pre-fire plant canopy area

When considering all samples (Table 10), the canopy area of the pre-fire plant was significantly correlated to the number and length of resprouts on spring (number: $\rho=0.270$, $p=0.013$; length: ($\rho=0.311$, $p=0.004$) and summer (number: $\rho=0.546$, $p=0.000$; length: $\rho=0.310$, $p=0.004$), with its significance increasing over time in the case of number of resprouts. Canopy area was also significantly correlated to resprout diameter in the first campaign ($\rho=0.339$, $p=0.002$).

Several other correlations were observed in more specific groups. Pre-fire canopy area was also significantly correlated to the number and length of resprouts on plot 1 shrubs during the second field campaign ($\rho=0.588$, $p=0.044$; $\rho=0.685$, $p=0.188$, respectively). On plot 3, during spring, it was observed a significant correlation to the number of resprouts ($\rho=0.411$, $p=0.01$) and, during summer, number of resprouts ($\rho=0.455$, $p=0.003$) and length ($\rho=0.436$, $p=0.008$). All shrubs were also positively correlated to canopy area during spring on length ($\rho=0.262$, $p=0.024$) and diameter ($\rho=0.237$, $p=0.042$), and during summer on the number of resprouts ($\rho=0.445$, $p=0.126$) and length ($\rho=0.297$, $p=0.011$).

Plot 2 trees also presented perfect correlations to several metrics, but it should be noted that only 3 individuals belong in that group.

Table 10- Spearman correlation values (ρ) and significance measures (p) for the correlation between pre-fire plant canopy area and number, maximum length and maximum diameter of resprouts.

		Spring		Summer		N
		ρ	p	ρ	p	
Plot 1	No. resprouts	0.443	0.065	0.345	0.125	22
	Length	0.204	0.418	0.401	0.099	
	Diameter	0.195	0.438	0.125	0.622	
Plot 1 shrubs	No. resprouts	0.495	0.145	0.588*	0.044	12
	Length	0.321	0.365	0.685*	0.188	
	Diameter	0.261	0.467	0.188	0.603	
Plot 1 trees	No. resprouts	-0.038	0.928	-0.252	0.513	10
	Length	-0.667	0.071	0	1	
	Diameter	0.048	0.911	0.19	0.651	
Plot 2	No. resprouts	-0.005	0.978	0.358	0.056	30
	Length	0.44	0.82	0.303	0.098	
	Diameter	0.075	0.699	0.247	0.197	
Plot 2 shrubs	No. resprouts	-0.147	0.474	0.296	0.142	27
	Length	0.005	0.979	0.251	0.216	
	Diameter	0.002	0.993	0.175	0.393	
Plot 2 trees	No. resprouts	1**	.	1**	.	3
	Length	0.5	0.667	1**	.	
	Diameter	0.5	0.667	0.5	0.667	
Plot 3	No. resprouts	0.411*	0.01	0.455**	0.003	40
	Length	0.234	0.158	0.436**	0.008	
	Diameter	0.073	0.661	0.217	0.204	
Shrub	No. resprouts	0.225	0.054	0.445**	0.126	79
	Length	0.262*	0.024	0.297*	0.011	
	Diameter	0.237*	0.042	0.126	0.292	
Tree	No. resprouts	0.005	0.989	0.179	0.577	13
	Length	0.159	0.64	-0.082	0.811	
	Diameter	0.236	0.484	-0.345	0.298	
Total	No. resprouts	0.270*	0.013	0.546**	0.000	92
	Length	0.311**	0.004	0.310**	0.004	
	Diameter	0.339**	0.002	0.133	0.232	

**correlation is significant at the 0,01 level
* correlation is significant at the 0,05 level

4. Discussion

In this study it was possible to observe that *Arbutus unedo* strongly resprouts after a severe fire. Total mortality was very low (2.18% didn't regenerate by the time sampling was finished), with some only resprouting after the first growth season.

All *A. unedo* sampled on all three Plots were top-killed. Even though no soil litter was found and ash colour was homogeneous in all sampled specimens, a small difference in thinnest twigs could be observed on some plants, meaning some were slightly more consumed by fire. Globally these indicators point towards a moderate to severe fire (Keeley 2009). Therefore, a fire severity index was used based solely on the thinnest twig diameter. Attending to *Arbutus unedo*'s ecology, the use of this method to predict resprouting vigour has its limitations since regeneration occurs from underground dormant buds and only the aboveground parts were differently affected by fire. Even with all limitations in mind, it was still observed that fire severity was negatively correlated to the total number of resprouts obtained on the first growth season but not on the second (when considering the entire dataset). These results suggest that a higher fire severity could hinder regeneration early on but its effect diminishes over time. Also, since *Arbutus unedo* resprouted in abundance over the course of the year this could indicate that fire severity is not a very good predictor for regeneration over the years but instead should be used as an indicator of initial resprouting vigour (Keeley et al. 2008). After the initial resprout, the plant's canopy area increases and gets more capable of obtaining carbohydrates through photosynthesis and thus the effect of fire severity on its vigour diminishes over time. Lastly, fire severity was negatively correlated with pre-fire plants' canopy area on plots 1, 3, plot 1 shrubs and all shrubs together but not for other plots or for the entire dataset. Even though, it should be noted that plant size and fire severity are not completely independent variables. A larger plant has considerably more biomass to be used as fuel by fire than a smaller plant (Keeley et al. 2008). The same concept should apply when comparing wild, unmanaged trees with planted, managed and thinned trees. These factors could explain the results obtained for plot 3 (only composed by unmanaged shrubs) and shrubs overall as well as the higher mean finest twig diameter observed on plot 3.

Just like on fire severity analysis, only very few subsets of pre-fire plant data were able to be significantly correlated to regeneration metrics. This could be due to a lacking number of total samples. Therefore, it was not possible to establish a relationship between each plot's history and plant types with the regenerating sprouts. Still, it was observed that previously tree-like *Arbutus unedo* were now resprouting with more than one sprout per plant, which would characterize them as shrub-like plants. This indicates that rather than being two different types of trees, *Arbutus unedo* type is dependant on disturbance history.

Overall, pre-fire plant length and diameter were correlated to resprouts length and diameter, respectively, on both seasons. Pre-fire plant height significantly affected the length and diameter of resprouts on the first growth season and their number and length on the second. Similarly, canopy area was correlated to all but resprout diameter in summer. Hence, results suggest that it is indeed possible to predict regeneration based on pre-fire plant size and larger plants should be able to resprout more vigorously after fire. These results are slightly different from those obtained on a similar study on *Arbutus unedo* (Konstantinidis et al. 2006) as well as other post-fire resprouting species (Lloret and López-Soria 1993), as they report pre-fire plant size to only have a significant effect only after the second growth season, unlike in this experiment where it's possible to already see them in the first growth season. In fact, results showed that length and diameter grow slow and steadily correlated from the first growth season ($\rho=0.234$, $p=0.031$; $\rho=0.279$, $p=0.010$, respectively) to the second growth season ($\rho=0.250$, $p=0.022$; $\rho=0.290$, $p=0.008$, respectively). Pre-fire plant size and aspect is used as an indicator of a plant's age, and thus, the growth of underground parts. It is expected of a larger tree to have a greater rooting system and more stored carbohydrates on the lignotuber than a smaller one. As mentioned by Konstantinidis, Tsiourlis, & Xofis, 2006, growth of resprouts is believed to be dependant of the lignotuber on the early stages of development (first growth season) since its growth is done by stored carbohydrates and the root system on the later stages, where the plant needs more nutrients and water from the soil. Therefore, a greater rooting system may be able to provide a richer pool of nutrients as well as a bigger water intake to the plant, which would result in a more vigorous resprout. All in all, pre-fire plant size should be a better predictor of regeneration than fire severity. However, environmental disturbances can hinder this aboveground/belowground relationship. While the planted strawberry trees in this study weren't subjected to disturbances, it is known that the spontaneous trees have been under previous wildfires and posterior salvage logging, as well as thinning. It is also possible they sprouted on different years. Therefore, it is possible some of the trees may have similar height and width, but different root system, which could possibly result in different resprouting vigours. Although *Arbutus unedo* are very resilient and resprouting was extremely successful in this study even among the smaller trees, it should be noted that this year was very atypical in terms of weather conditions (IPMA 2018a; IPMA 2018b). Previous studies suggest that extreme droughts on consecutive years may lead to reduced carbon assimilation and depletion of stored carbohydrates which, ultimately, lead to higher resprout mortality (Pratt et al., 2014; Van Nieuwstadt & Sheil, 2005). So, even though Portugal has been facing extreme droughts (IPMA 2017a; IPMA 2017b) over the past years and the 2017 forest fire having top-killed all sampled trees, this years' heavy rains and cooler spring may have potentiated *Arbutus unedo* resprouting capabilities and allowed the sampled specimens to thrive and resprout vigorously.

Finally, it was possible to observe that most measurements taken on the field are very highly redundant. Branch height and plant height had a correlation of $r^{2=}0.92$, while plant height and branch diameter was $r^{2=}0.68$ and branch diameter and branch length were $r^{2=}0.79$, same as basal diameter (which had very few samples since there weren't many tree-like samples) and branch length. Given the fact that plant height and branch height were so highly correlated between each other and since both of these measures were significantly correlated with the same regeneration metrics further proves that measuring plant height and branch length is highly redundant. These results suggest that in the future, whenever doing similar field work with limited time and on a budget, there isn't a dire need to repeat all of these procedures. The safest measure to take would be branch diameter since it's the most conservative measure, unlike branch or plant height that can be tampered with by thinning or severe burn, and it will still be a very good predictor of overall plant regeneration vigour. Crown diameters along with plant height measurements however are the best indicators of the overall shape and size of a plant and they allow us to estimate the photosynthetic area available to the plant prior to fire.

5. Conclusions

The *Arbutus unedo* population portrayed in this study was able to vigorously regenerate after a severe fire, with very low mortality in all three plots, regardless of differences in previous disturbances and forest management. Somewhat surprisingly, even the very young planted strawberry trees were able to survive fire, with only 1 plant showing no signs of vegetative regeneration after the second field campaign.

The overall resprouting ability was significantly associated with the initial (pre-fire) plant size, implicating that larger plants were able to resprout stronger and grow faster, at least in this study area.

Fire severity was also found to affect the initial plant resprouting capacity. The results suggest that the strawberry trees with a higher crown fire consumption produced less resprouts on the first growth season. However, this relation was not apparent in the end of the second campaign, indicating that potentially, for future studies, the assessment of post-fire regeneration could be delayed until the end of the dry season following fire.

Lastly, in future studies with similar objectives, sampling methodology could also be focused solely on measuring the largest branch diameters. This was the faster, thus cheaper, measure to sample on the field, while providing with satisfactory predictions of post-fire response of *Arbutus unedo*, showing correlations with the other plant measures. Additionaly, this measure is also the most reliable one, particularly in areas such as the present study area, where post-fire disturbances (e.g. wood harvest) can limit the accessibility to other pre-fire plant measurements.

6. Future research perspetives

In this study we accessed if and how well *Arbutus unedo* resprouts after fire without any human intervention. Results are quite optimistic and suggest that there is no urgent need for management after fire in what concerns plant replacement or plantation due to lack of regeneration. However, attending to the fact that these strawberry trees may be explored for its fruit and other products such as honey, this opens new opportunities for research and raises some questions:

1) does thinning improve overall length and diameter of retained resprouts? **2)** does it fasten flower/fruit production? **3)** could it influence the overall size and quality of the fruit? **4)** does this management make the plant more/less susceptible in the case of a recurrent forest fire?

With these questions in mind, strawberry trees in each plot were selected based on the pre-fire plant overall shape and size as well as on the resprouts length and diameter and paired up. In each pair one plant would serve as a control and the other was thinned, with dead branches cut and left with 3 to 6 remaining resprouts (Quevedo et al. 2013) (Figure 11). Over the next years, all plants will be monitored and thinned plants will be continuously thinned in order to maintain the number of resprouts/branches constant over time.

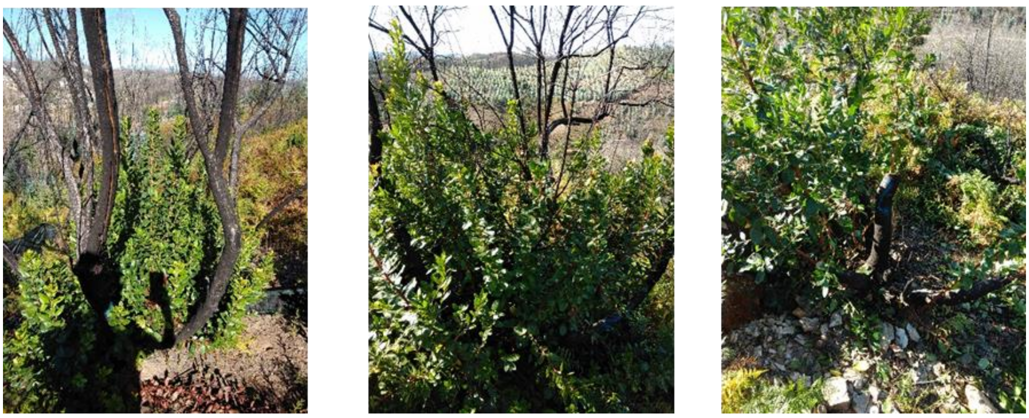

Figure 11- A side by side comparison of *Arbutus unedo* paired samples. Left image is the control plant, centre image is the test sample before thinning and the right is the same plant after thinning.

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Supplementary Material

Supplementary Material 1- Field sheet used to describe post-fire *Arbutus unedo* samples.

Alva Medronheiros Descriptive Sampling - **Burnt** Strawberry Trees

Site | DATE
Plant #
Planted/Spontaneous | regenerating already?
Picture | number of sprouts
Field mark plant | picture sprouts

Plant Descritpion | plant height | crown diameter
Type | **Srub like** | **tree like** | height of branching (cm) | managed?
Basal diameter | previous fires?

Branch diam (mm)	1	2	3	4	5	6	7	8	9	10
1st order										
note:										
Branch length										
Note:										
Diam Finest twig										
note:1 cm from the tip										

Micro Site Descritpi radius 2 m from center of the plant | 5 points soil description radially, 1 m from the center

Soil Cover | **rocks %** | **litter depth** | **main ash colour** | **ash depth** | **fallen litter**
litter %
ashes %
bare soil %
reg. Vege. %

Neighbouring Plants

	sp	height	crown diam	stem basal
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Supplementary Material 2- Field sheet used to describe *Arbutus unedo* resprouts on the first and second field campaigns.

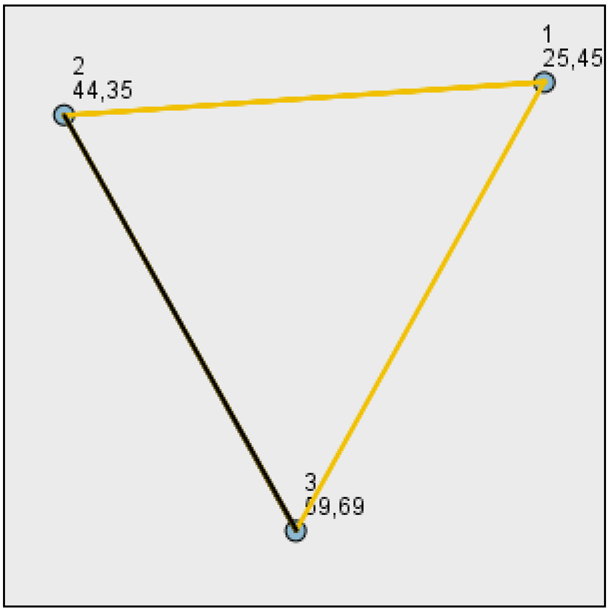
PLANTA

a regenerar?
nº rebentos

	red	green	blue	brown	white
diâmetro					
comprimento					
nº ramos					
nº gomos					
nº folhas					
afídeos					

Supplementary Material 3- Pairwise site comparison in Kruskal-Wallis test between thinnest twig diameters.

Comparações Pairwise de SITE



Cada nó mostra o posto médio de amostra de SITE.

Amostra 1-Amo...	Estatística de Teste	Std. Erro	Erro Estatística de Teste	Sig.	Sig. Ajust.
1-2	-18,895	7,494	-2,521	,012	,035
1-3	-34,233	7,087	-4,830	,000	,000
2-3	-15,338	6,449	-2,378	,017	,052

Cada linha testa a hipótese nula que as distribuições da Amostra 1 e da Amostra 2 são as mesmas.
São exibidas significâncias assintóticas (teste de 2 lados). O nível de significância é ,05.

Supplementary Material 4- Field photographs of an *Arbutus unedo* sample over the course of the year. 1) autumn 2017 (post-fire); 2) spring 2018 (first campaign); 3) summer 2018 (second campaign); 4) summer 2018 (post thinning).

1)

2)

3)

4)

Supplementary Material 5- Spearman correlation values (ρ) and significance measures (p) for the correlation between fire severity index and pre-fire plant length, diameter, height and canopy area.

		Fire severity		N
		ρ	p	
Plot 1	length	-0.371	0.089	30
	diameter	0.022	0.923	
	height	-0.371	0.089	
	canopy	-0.477*	0.025	
Plot 1 shrubs	length	-0.587*	0.045	12
	diameter	-0.217	0.499	
	height	-0.518	0.084	
	canopy	-0.685*	0.014	
Plot 1 trees	length	0.055	0.881	10
	diameter	-0.006	0.987	
	height	0.03	0.934	
	canopy	-0.297	0.405	
Plot 2	length	0.192	0.309	30
	diameter	0.11	0.564	
	height	0.226	0.231	
	canopy	-0.077	0.685	
Plot 2 shrubs	length	0.202	0.312	27
	diameter	0.114	0.572	
	height	0.261	0.189	
	canopy	-0.118	0.556	
Plot 2 trees	length	0	1.000	3
	diameter	-1**	0.000	
	height	-0.5	0.667	
	canopy	-0.5	0.667	
Plot 3	length	-0.293	0.067	40
	diameter	-0.226	0.161	
	height	-0.199	0.219	
	canopy	-0.406**	0.009	
Shrubs	length	-0.073	0.522	79
	diameter	-0.169	0.137	
	height	-0.081	0.477	
	canopy	-0.229*	0.042	
Trees	length	0.198	0.517	13
	diameter	0.082	0.789	
	height	0.11	0.721	
	canopy	0.022	0.943	
Total	length	0.129	0.221	92
	diameter	0.033	0.757	
	height	0.112	0.287	
	canopy	-0.008	0.941	

**correlation is significant at the 0,01 level

* correlation is significant at the 0,05 level

Supplementary Material 6- Overall post-fire regeneration metrics in spring (first campaign).

		No. resprouts	Length (cm)	Diameter (mm)	Branches	Leaves	Buds	N
Plot 1	x̄	5.41	23.17	4.41	4.68	17.32	1.14	22
	std	4.56	14.13	2.37	4.58	10.35	1.52	
Plot 1 shrubs	x̄	8.3	27.97	5.33	21.1	8.5	3	12
	std	4.64	12.17	1.33	8.25	4.09	1	
Plot 1 trees	x̄	4.5	28.75	5.45	21.25	6.5	2.5	10
	std	2.27	5.74	1.01	4.95	3.12	1	
Plot 2	x̄	10.7	41.47	8.09	9.3	28.87	5.23	30
	std	11.99	19.1	6.34	8.4	11.64	4.64	
Plot 2 shrubs	x̄	11.62	43.54	8.63	30.69	13.55	6.57	27
	std	12.42	18.55	6.56	10.72	6.99	4.44	
Plot 2 trees	x̄	6.33	37.33	6.17	22.67	4	3	3
	std	7.57	7.02	1.39	3.06	2.83	1.41	
Plot 3	x̄	8.28	35.23	7.44	13.25	9.65	3.83	40
	std	16.84	18.72	2.29	7.84	11.78	3.98	
Shrubs	x̄	9.68	38.12	7.77	28.35	13.74	5.23	79
	std	14.39	17.68	4.15	10.48	6.81	4.64	
Trees	x̄	5	31.09	5.65	21.64	6	2.67	13
	std	3.97	7	1.1	4.41	3.09	1.03	
Total	x̄	9.07	37.21	7.5	27.48	12.67	5.23	92
	std	13.58	16.83	3.96	10.14	6.95	3.93	

Supplementary Material 7- Overall post-fire regeneration metrics in summer (second campaign).

		No. resprouts	Length (cm)	Diameter (mm)	Branches	Leaves	Buds	N
Plot 1	x̄	7.48	81.41	11.42	10.45	48.64	2.36	22
	std	4.14	40.40	5.97	7.66	22.38	2.42	
Plot 1 shrubs	x̄	9.25	96.00	13.31	58.40	14.44	3.11	12
	std	3.74	24.47	3.61	7.40	6.02	1.96	
Plot 1 trees	x̄	5.78	103.88	14.77	60.75	12.50	3.43	10
	std	2.99	14.72	3.47	7.69	6.28	2.76	
Plot 2	x̄	19.40	102.60	13.07	18.30	65.57	6.87	30
	std	13.78	34.60	4.90	12.60	21.02	6.97	
Plot 2 shrubs	x̄	21.15	108.88	13.98	69.62	19.96	8.65	27
	std	13.69	26.97	4.18	16.29	12.22	6.98	
Plot 2 trees	x̄	10.67	82.33	9.52	52.33	10.00	3.50	3
	std	8.08	43.32	3.74	21.55	11.36	2.12	
Plot 3	x̄	21.73	101.58	15.62	20.33	52.35	6.80	40
	std	12.70	48.01	6.76	12.09	23.92	5.99	
Shrubs	x̄	19.62	109.08	15.57	62.33	20.89	7.56	79
	std	12.82	31.36	4.57	16.54	10.74	6.06	
Trees	x̄	7.00	98.00	13.34	58.45	11.82	3.44	13
	std	4.82	25.06	4.15	12.23	7.40	2.51	
Total	x̄	17.93	107.61	15.28	61.82	19.65	7.07	92
	std	12.80	30.70	4.56	16.03	10.77	5.90	

Supplementary Material 8- Spearman correlation values (ρ) and significance measures (p) for the correlation between fire severity index and number, maximum length and maximum diameter of *Arbutus unedo* resprouts for each campaign.

		Spring		Summer		N
		ρ	p	ρ	p	
Plot 1	No. resprouts	-0.071	0.779	-0.063	0.787	22
	Length	-0.039	0.877	-0.104	0.681	
	Diameter	-0.042	0.868	-0.094	0.711	
Plot 1 shrubs	No. resprouts	-0.355	0.314	-0.545	0.067	12
	Length	-0.2	0.58	-0.236	0.511	
	Diameter	-0.224	0.533	0.188	0.603	
Plot 1 trees	No. resprouts	0.472	0.237	0.471	0.201	10
	Length	0.81*	0.015	0.333	0.42	
	Diameter	0.333	0.42	-0.69	0.058	
Plot 2	No. resprouts	-0.188	0.328	-0.479**	0.009	30
	Length	-0.206	0.285	-0.374*	0.046	
	Diameter	-0.339	0.072	-0.34	0.071	
Plot 2 shrubs	No. resprouts	-0.161	0.431	-0.522**	0.006	27
	Length	-0.193	0.345	-0.35	0.079	
	Diameter	-0.358	0.073	-0.327	0.103	
Plot 2 trees	No. resprouts	-0.5	0.667	-0.5	0.667	3
	Length	-1**	.	-0.5	0.667	
	Diameter	-1**	.	-1**	.	
Plot 3	No. resprouts	-0.253	0.126	0.031	0.849	40
	Length	-0.213	0.199	-0.232	0.173	
	Diameter	-0.18	0.279	-0.048	0.782	
All shrubs	No. resprouts	-0.316**	0.006	-0.027	0.816	79
	Length	-1.83	0.118	-0.186	0.118	
	Diameter	-1.07	0.363	0.086	0.474	
All trees	No. resprouts	0.192	0.572	-0.014	0.965	13
	Length	0.26	0.441	0.118	0.729	
	Diameter	-0.127	0.709	-0.573	0.066	
Total	No. resprouts	-0.230*	0.034	0.124	0.246	92
	Length	-0.098	0.372	-0.123	0.269	
	Diameter	0.028	0.796	-0.077	0.491	

**correlation is significant at the 0,01 level
* correlation is significant at the 0,05 level

Supplementary Material 9- Spearman correlation values (ρ) and significance measures (p) for the correlation between pre-fire plant length and the number, maximum length and maximum diameter of resprouts.

		Spring		Summer		N
		ρ	p	ρ	p	
Plot 1	No. resprouts	-0.24	0.924	0.113	0.625	22
	Length	-0.189	0.452	0.509*	0.031	
	Diameter	0.197	0.433	0.538*	0.021	
Plot 1 shrubs	No. resprouts	0.049	0.893	0.372	0.234	12
	Length	-0.127	0.726	0.758*	0.011	
	Diameter	0.333	0.347	0.394	0.26	
Plot 1 trees	No. resprouts	-0.179	0.672	-0.202	0.603	10
	Length	-0.31	0.456	-0.167	0.693	
	Diameter	-0.095	0.823	0.524	0.183	
Plot 2	No. resprouts	-0.034	0.863	0.184	0.34	30
	Length	-0.032	0.869	0.171	0.375	
	Diameter	-0.026	0.894	0.063	0.745	
Plot 2 shrubs	No. resprouts	-0.143	0.485	0.057	0.783	27
	Length	-0.081	0.695	0.11	0.592	
	Diameter	-0.139	0.497	-0.055	0.789	
Plot 2 trees	No. resprouts	0.866	0.333	0.866	0.333	3
	Length	0	1	0.866	0.333	
	Diameter	0	1	0	1	
Plot 3	No. resprouts	0.269	0.102	.502**	0.001	40
	Length	0.09	0.59	0.325	0.053	
	Diameter	0.144	0.387	0.24	0.158	
All shrubs	No. resprouts	0.132	0.261	0.430**	0	79
	Length	0.182	0.12	0.225	0.057	
	Diameter	0.246*	0.034	0.076	0.526	
All trees	No. resprouts	-0.059	0.864	0.167	0.603	13
	Length	0.326	0.327	-0.159	0.64	
	Diameter	0.118	0.729	-0.305	0.361	
Total	No. resprouts	0.163	0.137	0.538**	0	92
	Length	0.234*	0.031	0.250*	0.022	
	Diameter	0.361**	0.001	0.125	0.261	

**correlation is significant at the 0,01 level

* correlation is significant at the 0,05 level

Supplementary Material 10- Spearman correlation values (ρ) and significance measures (p) for the correlation between pre-fire plant diameter and the number, maximum length and maximum diameter of resprouts.

		Spring		Summer		N
		ρ	p	ρ	p	
Plot 1	No. resprouts	0.73	0.772	0.232	0.313	22
	Length	-0.231	0.356	0.226	0.367	
	Diameter	-0.011	0.964	0.28	0.261	
Plot 1 shrubs	No. resprouts	-0.116	0.749	0.152	0.637	12
	Length	-0.212	0.556	0.588	0.074	
	Diameter	0.042	0.907	0.442	0.2	
Plot 1 trees	No. resprouts	-0.128	0.763	-0.042	0.915	10
	Length	-0.643	0.086	-0.405	0.32	
	Diameter	-0.333	0.42	0.143	0.736	
Plot 2	No. resprouts	-0.066	0.734	0.198	0.303	30
	Length	-0.124	0.522	0.053	0.785	
	Diameter	-0.067	0.73	-0.016	0.936	
Plot 2 shrubs	No. resprouts	-0.179	0.381	0.11	0.593	27
	Length	-0.215	0.29	-0.027	0.897	
	Diameter	-0.19	0.352	-0.145	0.481	
Plot 2 trees	No. resprouts	0.5	0.667	0.5	0.667	3
	Length	1**	.	0.5	0.667	
	Diameter	1**	.	1**	.	
Plot 3	No. resprouts	0.296	0.072	.424**	0.006	40
	Length	0.046	0.782	0.276	0.103	
	Diameter	0.053	0.752	0.059	0.732	
Shrub	No. resprouts	0.195	0.097	0.364**	0.001	79
	Length	0.159	0.176	0.151	0.205	
	Diameter	0.165	0.159	-0.049	0.68	
Tree	No. resprouts	-0.084	0.806	0.267	0.401	13
	Length	0.196	0.564	-0.327	0.326	
	Diameter	0.082	0.811	-0.427	0.19	
Total	No. resprouts	0.228*	0.036	0.480**	0	92
	Length	0.223*	0.04	0.176	0.111	
	Diameter	0.279**	0.01	0.290**	0.008	

**correlation is significant at the 0,01 level
* correlation is significant at the 0,05 level